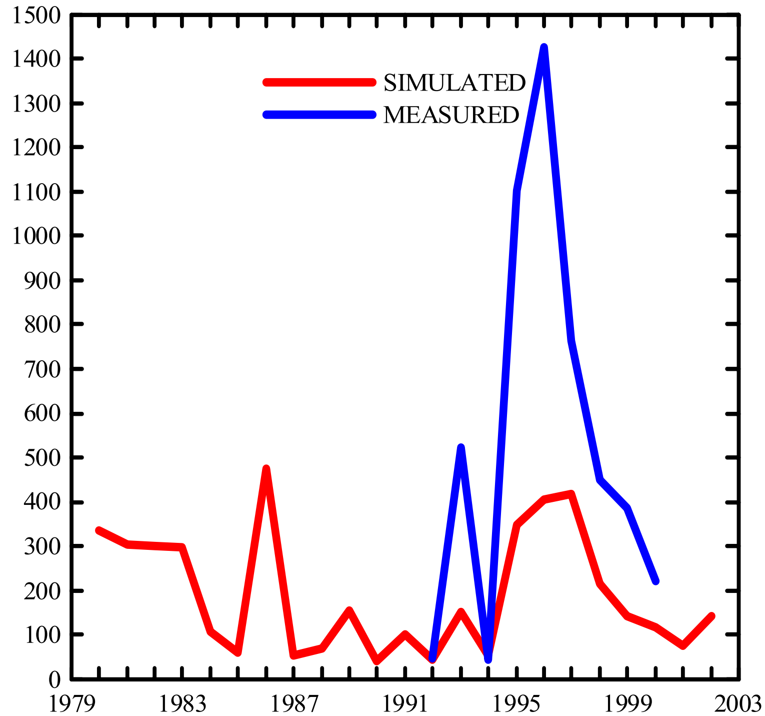

Figure 5-74. AnnAGNPS simulated and measured yearly sediment at the USGS gaging station 10336675, Ward Creek watershed.

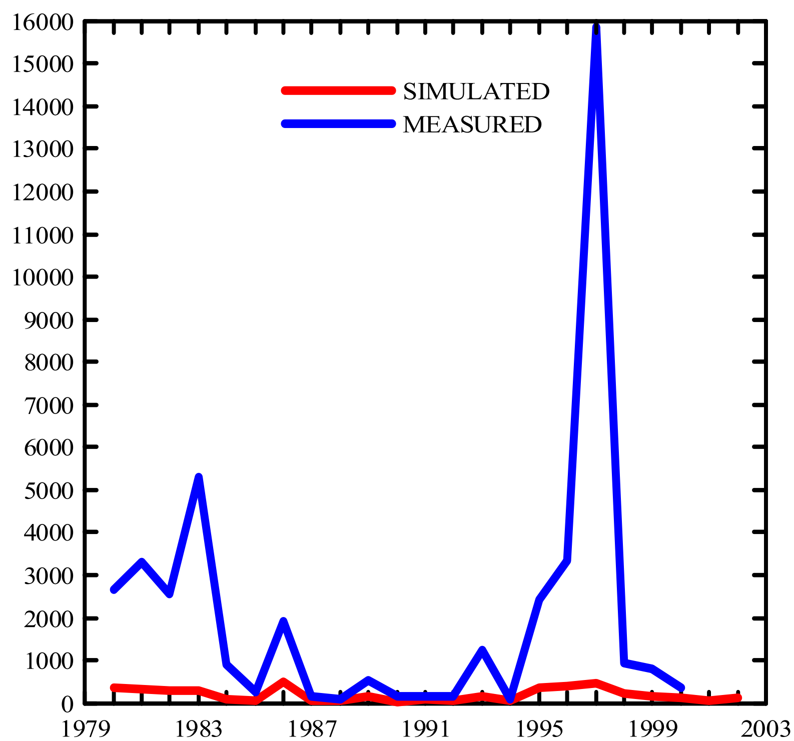

Figure 5-75. AnnAGNPS simulated and measured yearly sediment at the downstream station 10336676, Ward Creek watershed.

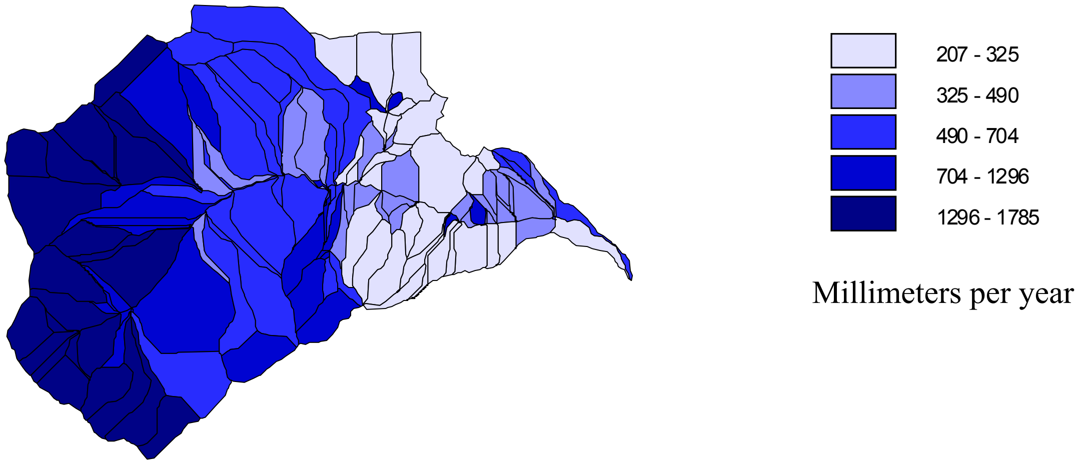

Figure 5-76. Average annual runoff simulated from AnnAGNPS for each cell on Ward Creek watershed.

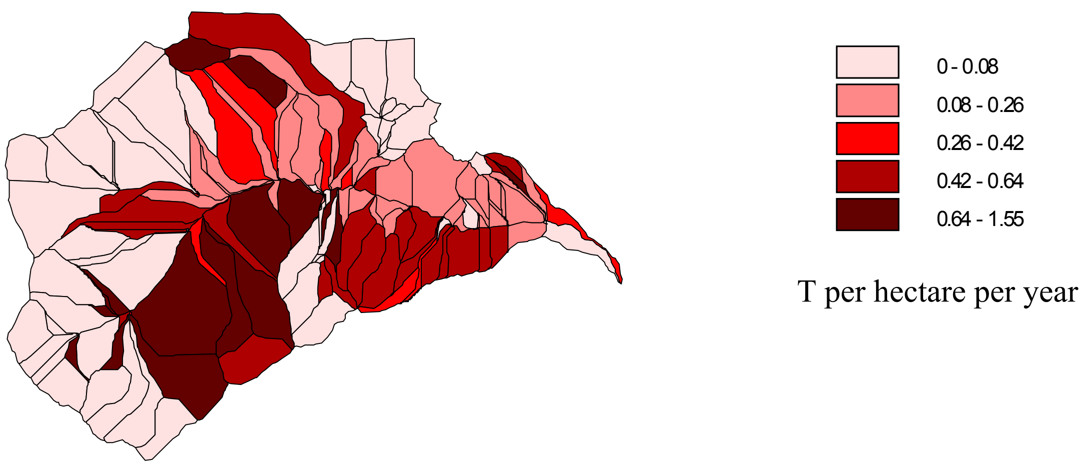

Figure 5-77. Average annual erosion simulated from AnnAGNPS for each cell on Ward Creek watershed.

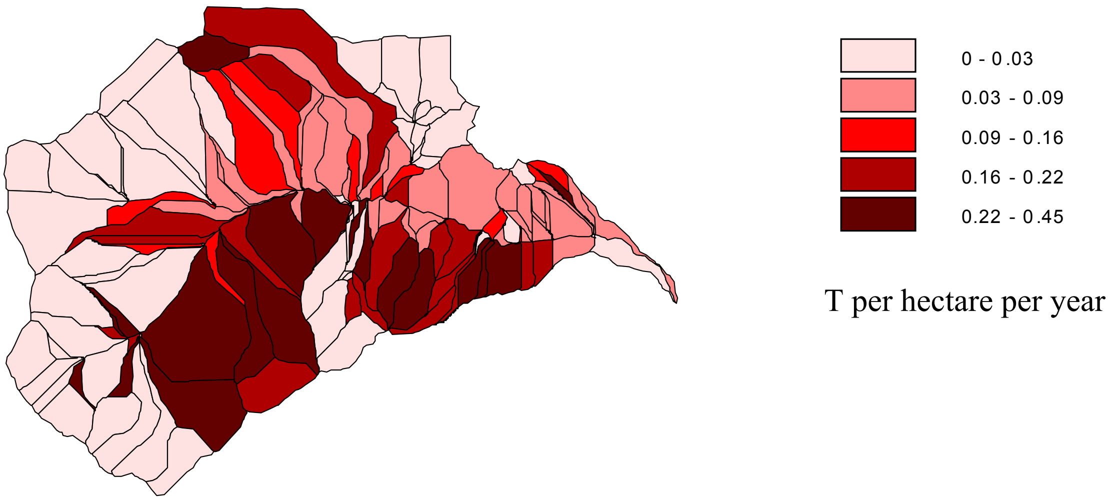

Figure 5-78. Average annual sediment yield simulated from AnnAGNPS for each cell on Ward Creek watershed.

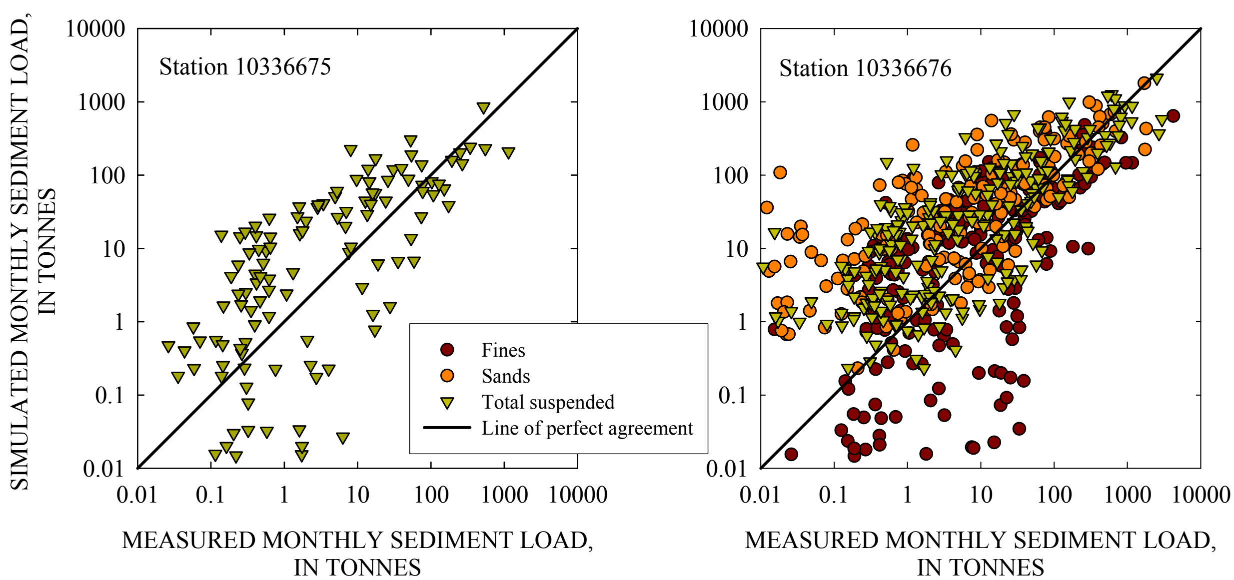

Figure 5-79. Comparison of measured and simulated mean-monthly loads of fines (clay and silts), sands, and total suspended sediment at Ward Creek.

CONCEPTS Validation

Estimated sediment loads at stations 10336675 and 10336676 (see section 3.4) were used to validate CONCEPTS for the period from January 1981 through September 2001. Figures 5-79 through 5-81 show the results of the validation. Simulated annual peak discharges are listed in Tables 5-14 and 5.15 and discussed above.

<u>Sediment Load</u>. Figure 5-79 compares measured and simulated mean-monthly loads of fines (clay- and silt-sized particles), sands, and total suspended sediments. The points plot

around the line of perfect agreement. The observed scatter is to be expected in light of the variability between measured and simulated mean-monthly runoff. At station 10336675 the r^2 value for total suspended sediments is 0.41. At station 10336676 the r^2 values for fines, sands, and total suspended sediments are 0.41, 0.52, and 0.56 respectively.

Generally, annual loads appear to be correlated with annual runoff (Figure 5-80). Years with low runoff correspond to years with low annual sediment loads. Increased measured loads in 1997 are caused by channel erosion, particularly bank widening during the January 1997 runoff event. Between 1992 and 2001 the measured average-annual total suspended sediment load was 504 T at gaging station 10336675. The corresponding simulated average annual load of total suspended sediment is 530 T. The simulated annual loads in 1995 and 1996 are smaller than those measured. However, simulated loads were already underestimated by AnnAGNPS at the upstream boundary of the model (station 10336674, see AnnAGNPS simulation). The simulated annual load in 1997 is larger than that measured and may be a function of either (1) the accuracy of the calculated load at the gage because it is much smaller than the annual load at the upstream station (10336674), and/or (2) as observed by Stubblefield (2002) and discussed in section 4.6.3, significant streambed deposition occurs between these two stations.

Between 1981 and 2001 the measured, average-annual fine, coarse, and total suspended sediment loads were 713, 1217, and 1930 T, respectively at the downstream, index station 10336676. The corresponding simulated average annual loads are 409, 1009, and 1418 T, respectively. The discrepancy between measured and simulated suspended load at station 10336676 is due to a large calculated sediment load on January 2, 1997. Omitting water year 1997 from the measured average annual load yields 523, 700, and 1223 T for fine, sand, and total suspended sediment load, respectively. The corresponding simulated average annual loads are 371, 923, and 1293 T, respectively. The simulated average annual load of fines (clays and silts) is underestimated whereas that of sands is overestimated.

Most sediment is transported during the snowmelt period from April through June (Figure 5-81). The simulated sediment loads during this period are somewhat under-predicted and is related to too much runoff in the fall and winter, and hence too little during the snow melt period.

Streambanks are the principal source of suspended sediment, contributing 86% of the sands and 66% of the total suspended sediment. Table 5-16 lists the sources of fines and sands delivered to the channel outlet and their relative contributions. Of the total amount of fines delivered to the channel 79% is eroded from the uplands and 21% from the streambanks.

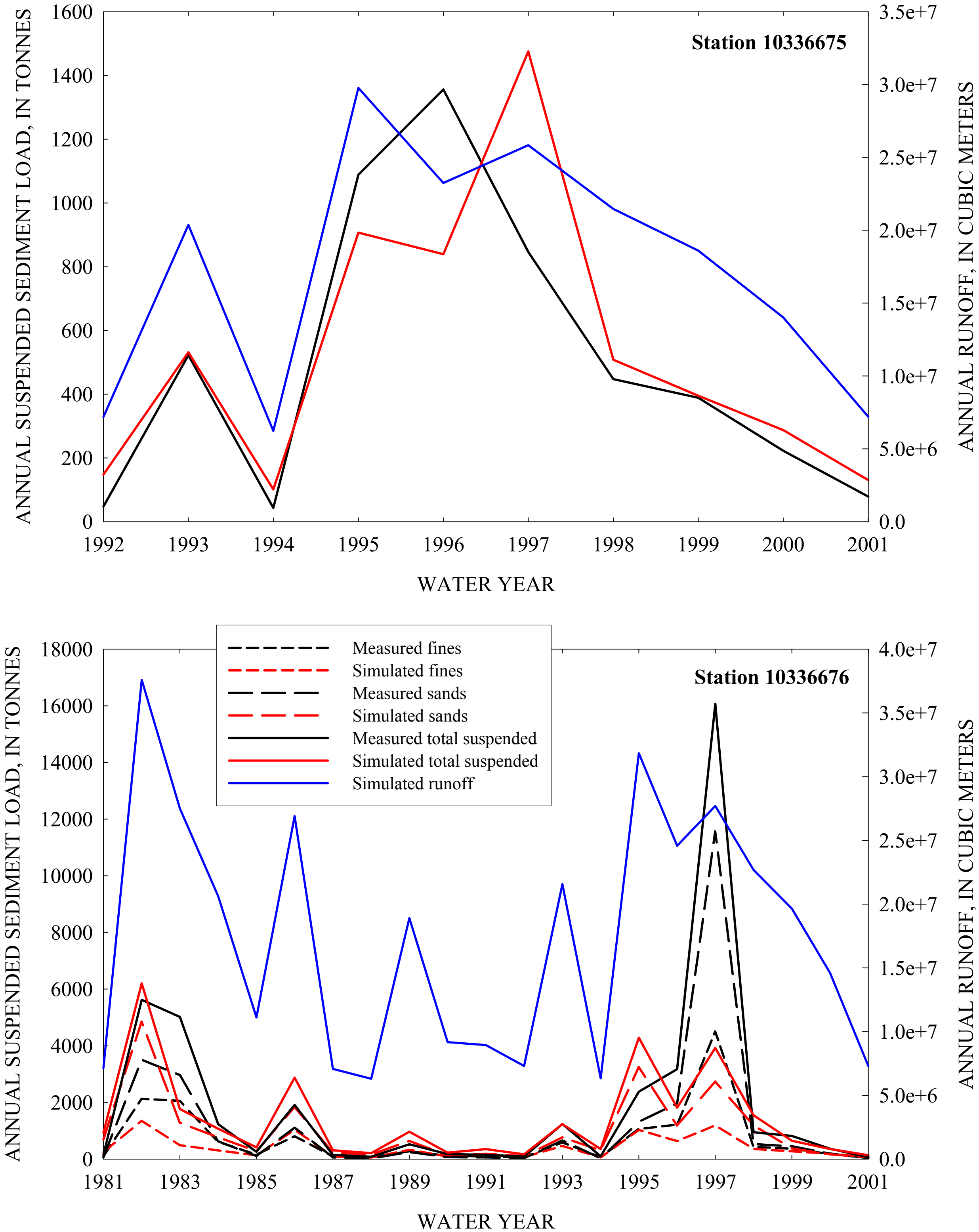

Figure 5-80. Comparison of measured and simulated annual loads at Ward Creek.

Table 5-16. Relative contributions of uplands and streambanks to suspended sediment load at the outlet of Ward Creek for the validation simulation.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	79	21	210
Sands	14	86	485
Total suspended	34	66	695

50-Year Simulation

A simulation with a 50-year flow record was performed to determine trends in sediment loads. The channel geometry is based on the 2002 cross section survey. All physical properties are those determined from the validation. The records of tributary and lateral inflow of water and sediments were constructed in the same way as the validation case. The runoff in years 24 through 46 is the same as in years 1 through 23 of the 50-year flow record, except the large storm event on January 2 of year 18 is not repeated in year 41 (see AnnAGNPS section). The runoff in years 47 through 50 is the same as in years 1 through 4.

Figure 5-82 shows the changes in channel top width and bed elevation over the 50-year simulation period. Top width changes only significantly at cross sections 2 and 14. Changes in thalweg elevation range from 0.05 m of erosion at cross section 9 to 0.12 m of deposition at cross section 14.

Figure 5-83 shows the simulated annual runoff, and annual loads of fines, sands, and total suspended sediments at the outlet of Ward Creek. The annual loads in years 1 through 23 are larger than those in years 24 through 50 though annual runoff is the same. Channel adjustments in the first 23 years are larger than those in years 24 through 50.

Table 5-17 lists the sources of fines and sands delivered to the channel outlet and their relative contributions. Of the total amount of fines delivered to the channel 84% is eroded from the uplands and 16% from the streambanks. Streambanks are the principal source of sediments, they contributed 86% of the sands and 61% of the total suspended sediment. Upland sources, however, are the main source of fine-grained materials from the watershed (Table 5-17).

Table 5-17. Relative contributions of uplands and streambanks to suspended sediment load at the outlet of Ward Creek for the 50-year simulation.

Sediment size	Uplands (%)	Streambanks (%)	Total (T/y)
Fines	84	16	200
Sands	14	86	353
Total suspended	39	61	553

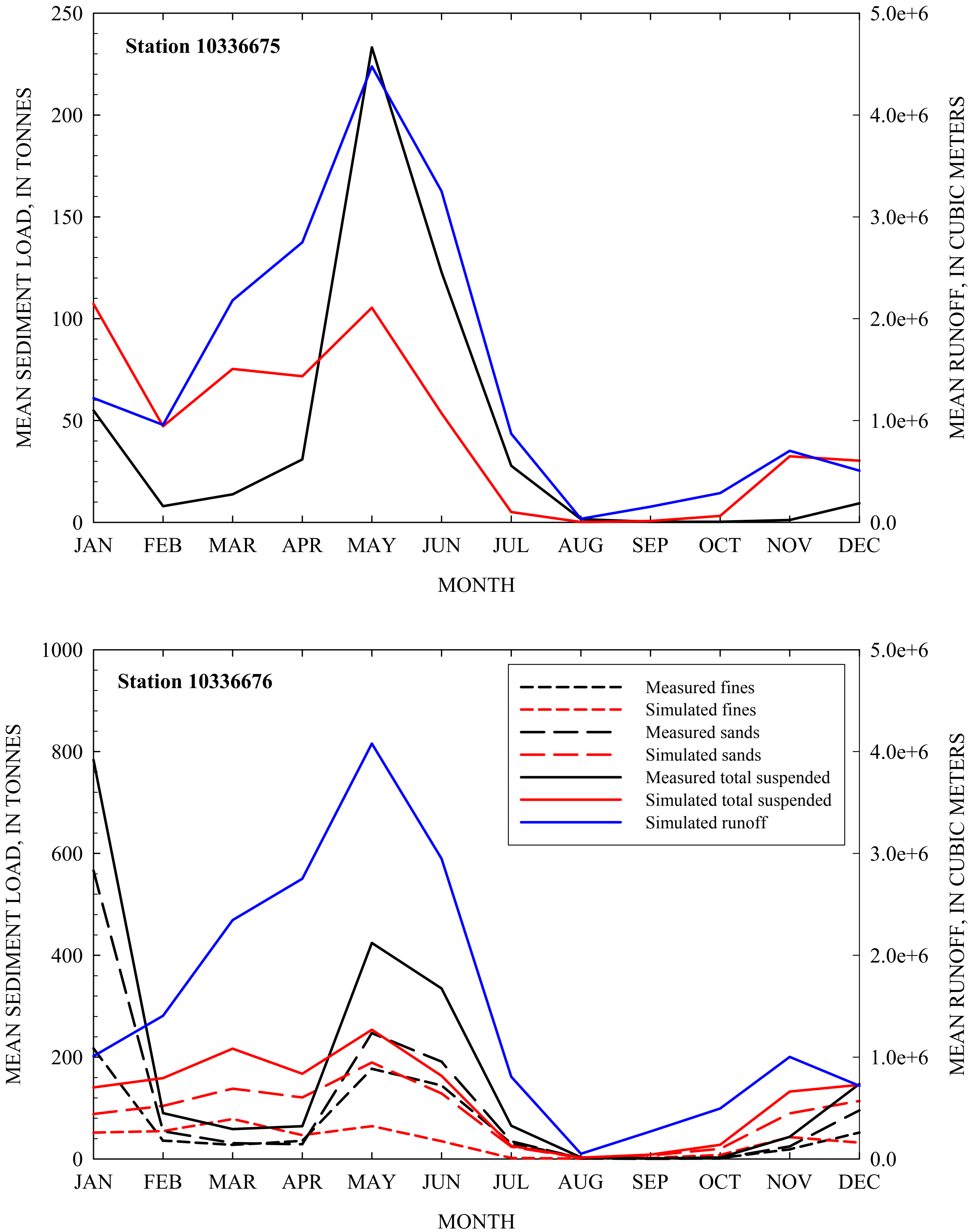

Figure 5-81. Comparison of measured and simulated annually-averaged monthly sediment loads and runoff at Ward Creek.

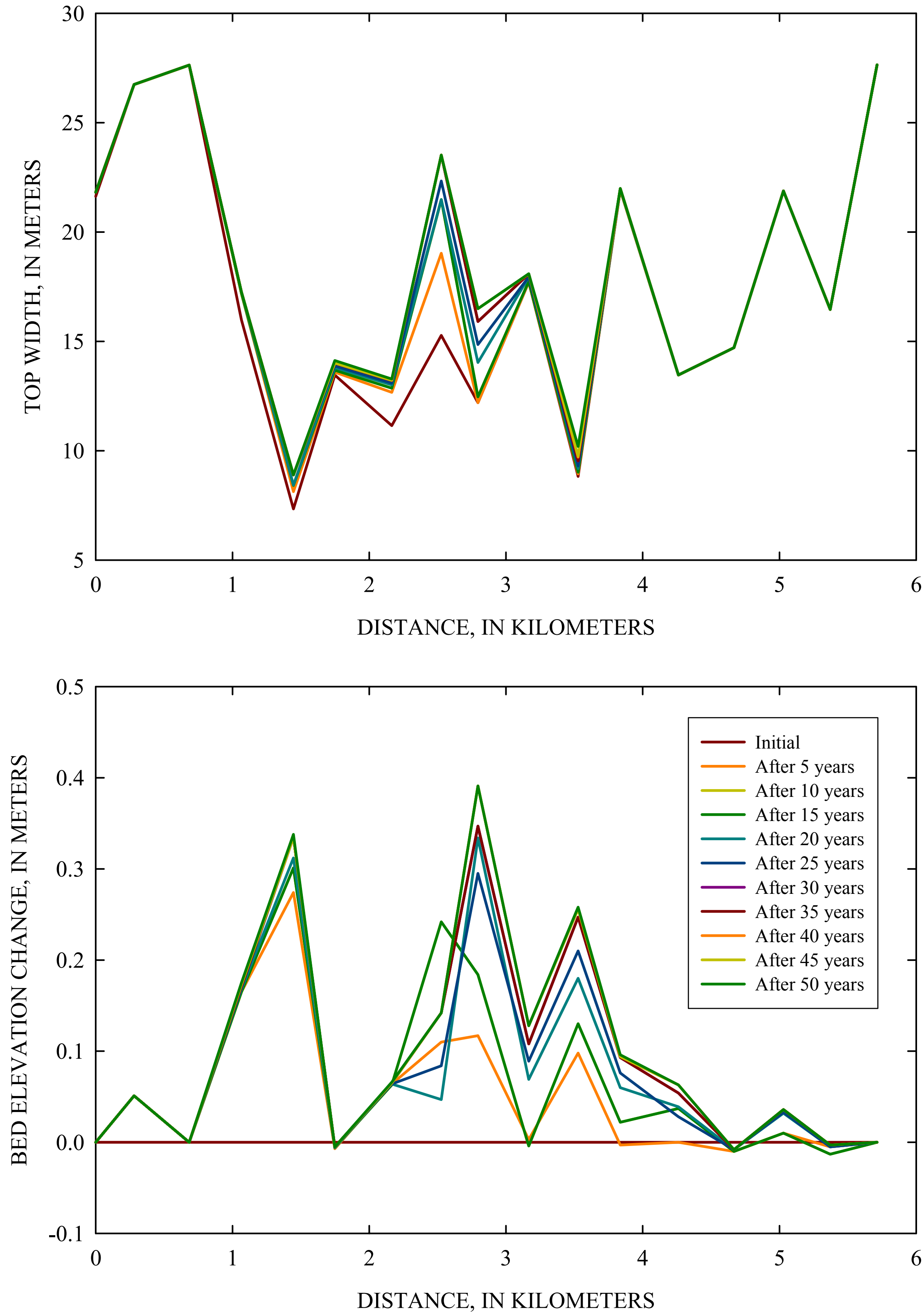

Figure 5-82. Simulated changes in bank top-width and bed elevation of Ward Creek over a 50-year period.

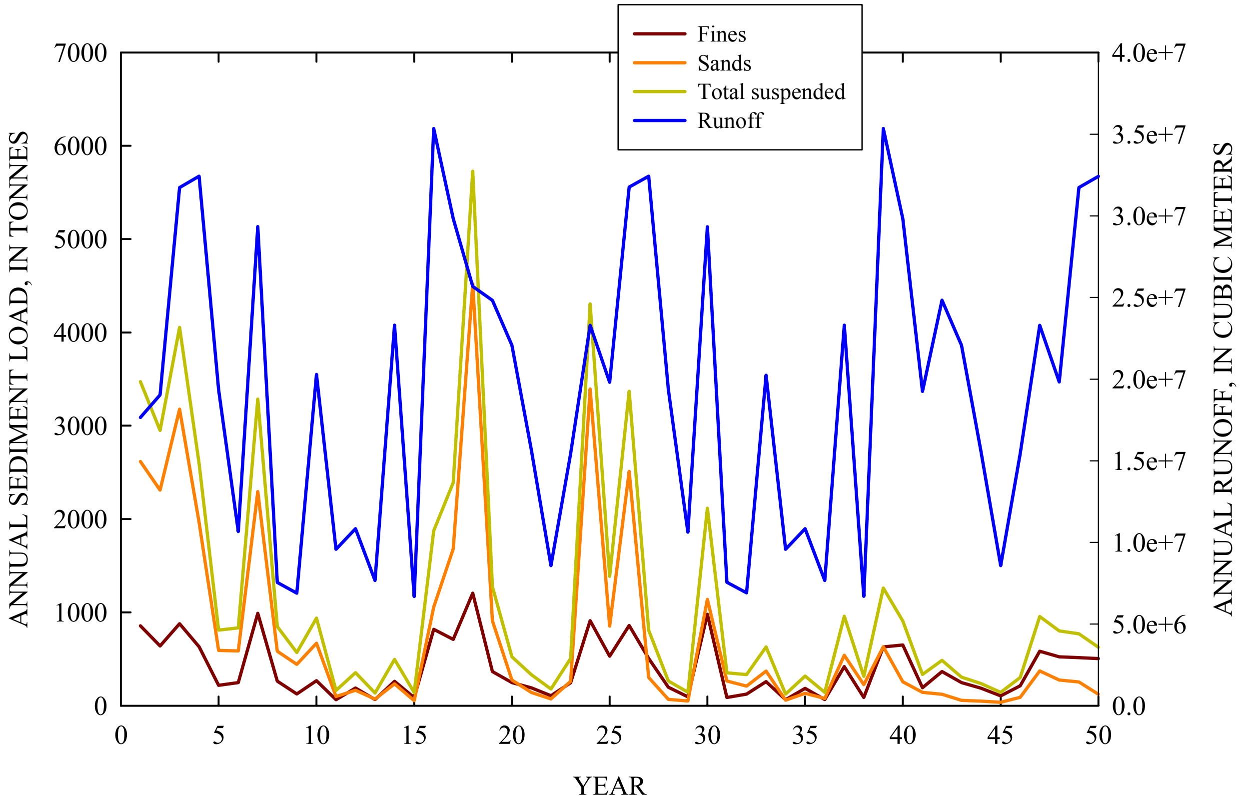

Figure 5-83. Simulated annual runoff and loads of fines, sands, and total suspended sediments at the outlet of Ward Creek for the 50-year simulation.

5.5 <u>Summary</u>

The USDA watershed and channel evolution models AnnAGNPS and CONCEPTS were used to simulate the sediment loadings to Lake Tahoe from General and Ward Creeks, and the Upper Truckee River over a 50-year period. The models were validated using: (1) discharges and sediment loads measured at USGS gaging stations in the three watersheds, and (2) measured changes in cross-sectional geometry at selected reaches of General Creek and the Upper Truckee River.

Climate information, particularly precipitation and temperature, is the most important factor to accurately simulate runoff. Unfortunately, the current climate data available for the Lake Tahoe Basin is inadequate for detailed numerical modeling in some watersheds. A 50-year numerical simulation of climate produced by a concurrent study was not available for this research. are very poor in most locations. For instance, there is no climate station located within the General Creek watershed. Precipitation and temperature at the Tahoe City climate station were used to represent the weather at General Creek watershed. For the Upper Truckee River watershed, accurate climate data are only available for its western-most region near Echo Lake. Climate data from Hagan's Meadow climate station (Trout Creek watershed) were used to complement the available data within the Upper Truckee River watershed. Both these stations are at high elevations (2440 m). Historic climate data at lower elevations in the Upper Truckee River watershed is limited to a few months that describe precipitation at the airport. The available climate data for Ward Creek watershed is better than for the other two watersheds.

Comparisons between simulated and measured data at the USGS gaging locations were made based on monthly and yearly totals to avoid the uncertainties involved with comparisons of individual dates. Also, AnnAGNPS has been designed for applications of long-term simulations; hence, individual event-based comparisons may distort how well the model actually performs.

The validation period for General Creek is 1981 to 2001. Cross -section surveys were carried out in 1983 and 2002. Simulated runoff volumes are lower than measured for General Creek (Figures 5-35 through 5-37), whereas peak discharges are high (Table 5-5). The applied precipitation used by the model was most likely too low at the upper end of the watershed. Simulated morphological changes and sediment loads agree very well with those estimated (Figures 5-43 through 5-46).

Average, annual suspended load at the downstream, index station (10336645) is 238 T, whereas AnnAGNPS and CONCEPTS simulated an average annual suspended load of 272 T. The difference is caused by an overestimation of the sand transport, which may be due to the model assumption that all sand-sized particles (diameter between 0.063 and 2 mm) are being transported in suspension. Still, these results are with 14%, an exceptional result given all of the inherent uncertainties.

Based on the simulation results, 72% of the fine suspended load (clay and silt) at the mouth of General Creek is contributed from the uplands and 28% from the channel. The coarse suspended load (sands) is mainly generated in the channel (60%). The simulated annual volumetric change in channel geometry per unit of channel length is 10.6 m^3/yr/km. This agrees quite well with that calculated from the surveyed change in cross section geometry (14.6 m^3/y/km). The simulated percentage of fine sediments (clay and silt) eroded from the channel is 8.5%, whereas the survey-based percentage of eroded fine sediments is 10.3%.

The 50-year simulation of General Creek predicts that 195 T/y of sediments are discharged into Lake Tahoe. Of this total, 51 T/y are clays and silts. The majority of sediments (60%) are generated in the first 25 years when channel-erosion processes are more active.

The validation period for the Upper Truckee River is 1981 to 2001. Cross section surveys for a highly active reach upstream of the airport were carried out between 1992 and 2002. Simulated runoff volumes (Figures 5-49 through 5-51) and annual peak discharges (Tables 5-8 through 5-10) along the Upper Truckee River are high compared to measured. The annual loads of suspended sediments are predicted fairly well at the mid-reach station (103366092) near Myers (Figure 5-63A). The simulated average annual load of suspended sediments is 1287 T compared with 1250 T measured. Simulated sand transport was higher than measured (2814 T versus 1700 T) at the downstream station (10336610) in South Lake Tahoe (Figure 5-63B), whereas the simulated average, annual fine-suspended load (1486 T) compares well with that measured (1258 T). Further, there is too much sediment transport during the fall and winter period, and too little during the spring (snowmelt) season (Figure 5-64).

Streambanks are the major source of sediments based on simulation results at the mouth of the Upper Truckee River: 49% of the fine suspended load (clay and silt), 90% of the coarse suspended load (sands), and 79% of the total suspended load. Simulated changes in bank-widening rates were reasonably good along the surveyed reach (between river km 11.7 and 13.7) (Figure 5-61). Difficulties were encountered in simulating toe erosion and incision in the reach on outside bends because CONCEPTS is a one-dimensional model.

The 50-year simulation of the Upper Truckee River predicts that annually 770 T/y of sediment will be discharged to Lake Tahoe. Of this total, 690 T/y are clays and silts. The majority of sediments (60%) are generated in the first 25 years when channel erosion, particularly bank widening is most active. Almost two-thirds of the total suspended-sediment is simulated to come from streambank erosion. Of the total mass of fine-grained sediments delivered to the lake over the 50-year simulation period, 37% are from streambanks, with the balance from upland sources.

The validation period for Ward Creek is 1981 to 2001. Simulated runoff volumes are lower than measured (Figures 5-68 and 5-69), but annual peak discharges are predicted fairly well (Tables 5-13 through 5-15). The simulated average annual suspended sediment load agrees quite well with those calculated from measured data (Figure 5-80): (1) 504 T (measured) versus 530 T (simulated) at USGS gaging station 10336675, and (2) 1223 T (measured) versus 1293 T (simulated) at USGS gaging station 10336676. The suspended load in water year 1997 has been omitted from the latter values, because the measured value for that year seems to be extremely large and may not be realistic. Based on the simulation results, 79% of the fine suspended load (clay and silt) at the mouth of Ward Creek is contributed from the uplands and 21% from the channel. The coarse suspended load (sands) is mainly generated in the channel (86%).

The 50-year simulation of Ward Creek predicts that annually 1150 T of sediments are discharged into Lake Tahoe. Of this total, 400 T are clays and silts, delivered primarily from upland sources (84%). The majority of sediments (70%) are generated in the first 25 years when channel erosion is more active.

The differences between simulated and measured runoff from the three watersheds can be significantly reduced with improved climate data, mainly precipitation and temperature. Precipitation and temperature are highly dependent on weather patterns and elevation (see Figures 5-21 and 5-22), and therefore, vary widely across each watershed. Precipitation will affect runoff volume, whereas temperature will determine whether precipitation occurs as rain or snow, and the timing of snowmelt. Hence, both simulated runoff volume and timing of runoff could be improved with better climate data, reducing the differences between measured and simulated runoff. Figure 5-31 shows that snowmelt can be represented by a triangular hydrograph superimposed on a certain base flow. However, AnnAGNPS and CONCEPTS do not simulate a base flow. Consequently, the constructed triangular hydrographs may have unrealistically high peaks. Determining the base flow during snowmelt may therefore lead to improved prediction of annual peak discharges.